Life-History Aspects of the Rainbow Shiner, Notropis chrosomus (Teleostei: Cyprinidae), in Northern Georgia

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Life-history Aspects of the Rainbow Shiner, *Notropis chrosomus* (Teleostei: Cyprinidae), in Northern Georgia

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Abstract - The life history of *Notropis chrosomus* (Rainbow Shiner) was investigated using 12 monthly collections from Moore Creek (Etowah River Drainage) at GA Highway 140 in Cherokee County, GA. Specimens were collected by electroshocking and seining primarily from runs and flowing pools and examined to identify feeding habits, age, growth, and reproductive patterns. *Notropis chrosomus* are opportunistic insectivores with gut contents largely consisting of Chironomidae larvae, unidentified insect parts, unidentified Diptera adults, and Collembola. Spawning occurred in spring with 400–896 (mean 708.92, SD = 162.90) mature oocytes ranging from 0.7 mm to 1.22 mm (mean = 0.90 mm, SD = 0.167 mm) present in specimens collected in April, May, and June. Sexual maturity occurred at approximately one year of age. The maximum age of both males and females was estimated at approximately 24 months (females = 25 months, males = 23 months). The largest female collected was 66.71 mm SL and 5.515 g total weight. The largest male collected was 60.19 mm SL and 3.691 g total weight.

Introduction

Notropis chrosomus (Jordan) (Rainbow Shiner) was described in 1877 from specimens collected in a tributary to the Etowah River near Rome, GA (Gilbert 1998). Hypothesized close relatives include *N. leuciodus* (Cope) (Tennessee Shiner) and *N. nubilus* (Forbes) (Ozark Shiner) (Mayden 1987) as well as *N. rubricroceus* (Cope) (Saffron Shiner) and *N. lutipinnis* (Jordan and Brayton) (Yellowfin Shiner) (Mayden et al. 2006). *Notropis chrosomus* is often abundant in small streams throughout the tributaries of the Etowah, Oostanaula, Cahaba, and Coosa River drainages of Northwest Georgia and Northeastern Alabama, and is distinguished from other cyprinids within its range by a red upper half of the eye; nuptial males possess a reddish stripe above the midlateral stripe and powder blue below with iridescent flecks of lavender, pink, and silver over the body (Boschung and Mayden 2004). Little is known of the biology of *N. chrosomus* other than the associated spawning with *Nocomis leptocephalus* (Girard) (Bluehead Chub) and *Campostoma oligolepis* Hubbs and Greene (Largescale Stoneroller) occurring from May to June, as determined from observations and the physical condition of museum specimens (Johnston 1991, Johnston and Kleiner 1994). The primary objective of this study is to elucidate some of the aspects of the life history of *N. chrosomus* and briefly compare them to those of hypothesized close relatives.

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Study Area

Specimens were collected from Moore Creek upstream of its confluence with Shoal Creek (34.3240ºN, 84.5636ºW), near Waleska in Cherokee County, GA (Fig. 1). Moore Creek is an upland second order tributary of the Etowah River between 3.1 and 6.4 m wide and less than 1.0 m deep at normal flows. Substrate is primarily gravel to cobble with sporadic bedrock in riffles, with gravel to sand in runs, and sand and silt in pools. Most *N. chrosomus* collected during this study were taken from runs to flowing pool habitat near the riffle edges. Upstream of the study area, the Moore Creek watershed is mostly forested with moderate agricultural use and sparse residential development. Water temperatures during times of collection ranged from 4 ºC in January 2006 to 25 ºC in June 2006. The species richness found for fishes within the study reach was relatively high, with 30 species collected. A complete list of species collected from Moore Creek near its confluence with Shoal Creek can be found in O'Kelley and Powers (2007).

Methods

Notropis chrosomus and vouchers of associated species were collected by sampling near the middle of each month using a 3.3-m x 1.3-m seine and a Smith-Root model 24 backpack electrofisher from January to December 2006. A total of 200 specimens were collected, preserved in 10% formalin, rinsed with water, and transferred into 70% EtOH for long-term storage. Specimens were accessioned into the University of Alabama Ichthyological Collection (UAIC 15027–15038). Observations for spawning behavior of

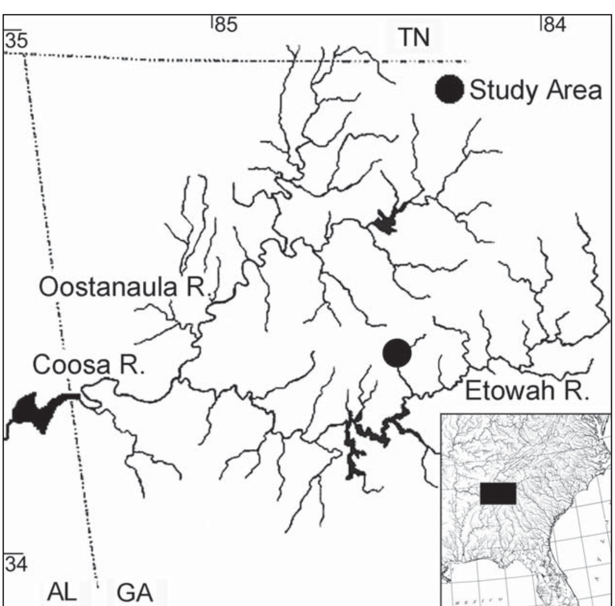

Figure 1. Map of *Notropis chrosomus* study area in Moore Creek (34.3240ºN, 84.5636ºW), near Waleska in Cherokee County, GA.

N. chrosomus were conducted in 10-minute intervals on 16 May 2007 by snorkeling and bank observations lasting approximately one hour.

The standard length (SL) of each specimen was measured using digital calipers and recorded to the nearest 0.01 mm. Sexual size dimorphism was detected using a two sample *t*-test of SL; therefore all analyses regarding age and growth were performed separately according to sex. Specimens were blotted dry and total weight (TW), eviscerated weight (EW), and gonad weight (GW) were measured using a digital analytical balance and recorded to the nearest 0.001 g. Standard length and EW were plotted against month to provide length and weight frequency distributions to illustrate age and growth data. All statistical analyses were executed using Data Desk 6.0 (Data Description, Inc., Ithaca, NY) with alpha for all tests equal to 0.05. In reference to regressions, independent variables are listed first and dependent variables second unless otherwise noted.

Standard length was plotted against month. Gaps of approximately 5 mm or more in the SL of specimens from a single month were considered indicative of different age classes. Frequency distributions of SL from selected months were also examined for peaks adjacent to categories lacking specimens to corroborate indications of different age classes by SL data (Fig. 2). Using May as an example, the frequency distribution category 45–50 mm entirely lacked specimens, but adjacent categories (40–45 mm and 50–55 mm) contained 3 or more specimens each suggesting two separate age classes in specimens collected in May.

Due to high GSI values found in specimens collected in April and May, as well as spawning behavior observed on 19 May 2007, we assumed spawning occurred in spring and used May as the month of spawning for age estimates.

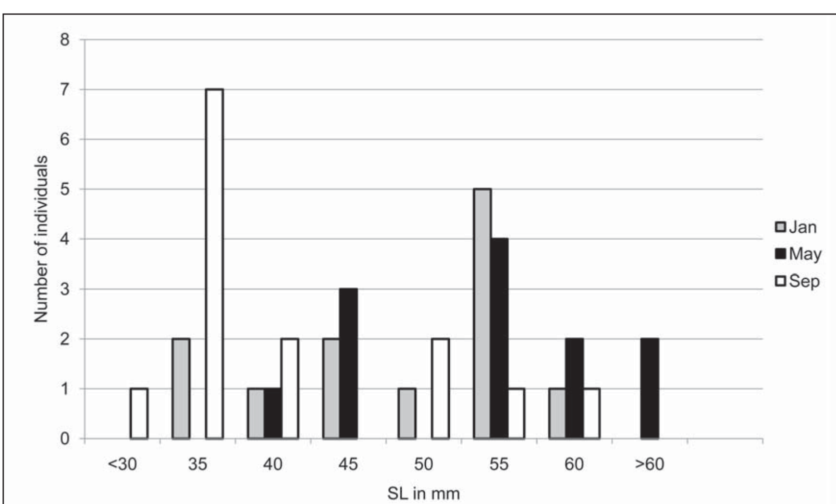

Figure 2. Frequency distribution of standard length (SL) in categories of 5 mm increments for *Notropis chrosomus* collected in January, May, and September 2006 from Moore Creek, Cherokee County, GA.

Specimens less than 12 months of age were counted as age 0+, specimens 12–23 months were counted as age 1+, specimens, and 24–35 months were counted as age 2+. The proportion of total specimens collected represented by each age class was calculated to approximate the age class distribution of the population. A Mann-Whitney test of age in months was used to test differences in lifespan among sexes. Regressions by least sum of squares were performed for SL and the natural log of EW.

The anterior third of the gastrointestinal track was opened and its contents were removed and weighed using a digital analytical balance and recorded to the nearest 0.001 g. Weight of gut contents for specimens with empty guts was recorded as "0." An ANOVA was performed to detect mean differences in weight of gut contents between months. Food items were identified to the lowest taxonomic category possible following Thorp and Covich (1991) and Merritt and Cummins (1996) and enumerated. Due to mastication by pharyngeal teeth, most gut contents were not identifiable below the family level, and some could only be identified to order or class.

Gonadosomatic index (GSI), was calculated by dividing GW by EW. An ANOVA was performed to detect mean differences in GSI from different months for males and females. Mature oocytes were categorized as latent, early maturing, late maturing, and mature (see Heins and Machado 1993). In gravid females, mature oocytes were enumerated and diameters of five representative mature oocytes were measured. The regression of SL was used as a predictor of the number of mature oocytes to test the influence of size on fecundity.

Results

The smallest specimen collected (19.28 mm SL and 0.095 g TW) was in July and presumed to be the earliest capture of a young-of-the-year specimen. The largest female collected was 66.71 mm SL and 5.515 g TW. The largest male collected was 60.19 mm SL and 3.691 g TW. The ratio of females to males collected was 0.96:1. Sexual size dimorphism was detected ($P = 0.006$) with mean SL of 47.83 mm (SD = 9.87) for females and 44.43 (SD = 8.35) for males. Due to this sexual size dimorphism, the following results are presented for females and males respectively unless otherwise noted.

As age in months increased, so did SL ($r^2 = 67.5\%$, $P < 0.001$; $r^2 = 66.4\%$, $P < 0.001$). Visual inspection of the data suggested a curvilinear relationship between SL and EW, so before regressing it with SL, we log transformed EW ($r^2 = 72.3\%$, $P < 0.001$; $r^2 = 69.3\%$, $P < 0.001$). Growth rates appear to increase in spring as indicated by length and weight increases in specimens approximately 1 and 2 years of age (Figs. 3–4). Of the 200 specimens collected, 44.2% were 0+, 54.3% were age 1+, 1.5% were age 2+. Mean age in months was different between the sexes ($P < 0.001$) with a mean age for males of 11.70 months (SD = 5.63) and for females of 13.46 (SD = 6.34). Maximum age of specimens captured was 23 months for males and 25 months for females.

Chironomidae larvae made up 44.6% of all gut contents of *N. chrosomus* examined. Unidentified insect parts, Diptera adults, and Collembola made

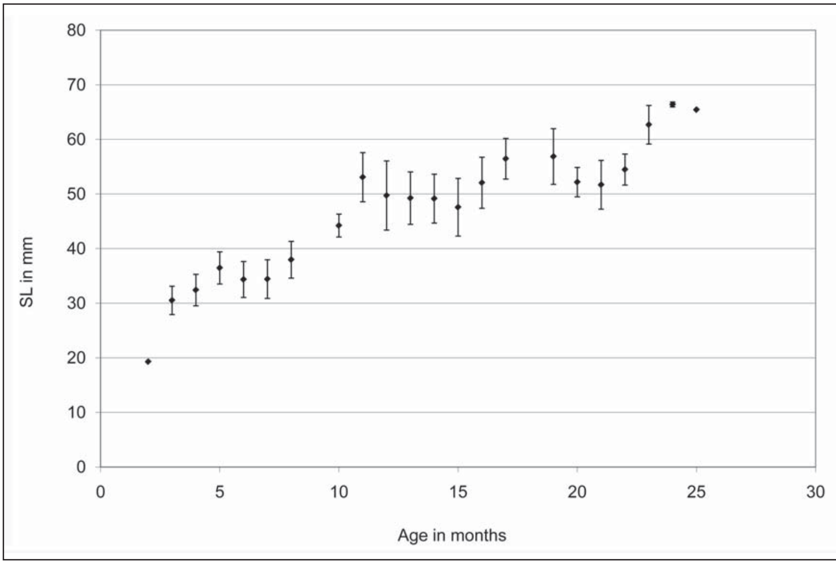

Figure 3. Standard length (SL) in mm ± one standard deviation by age in months for *Notropis chrosomus* collected from Moore Creek between January 2006 and December 2006.

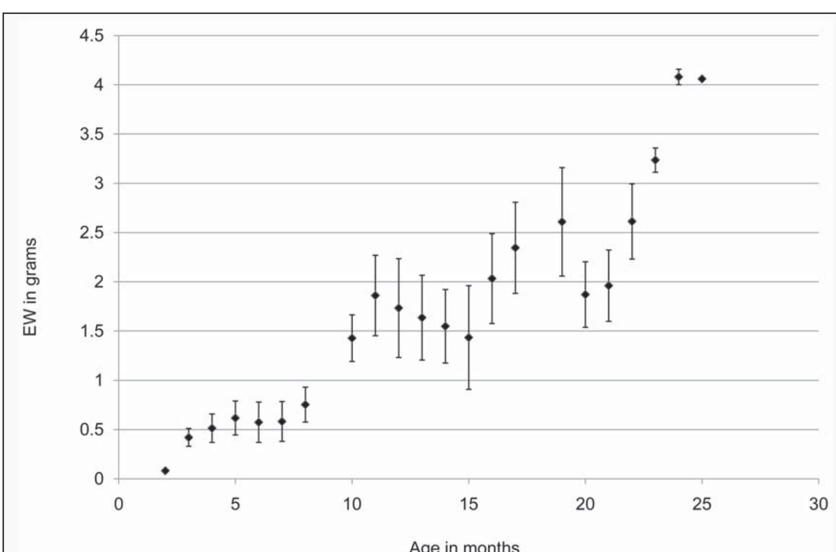

Figure 4. Eviscerated weight (EW) in g ± one standard deviation by age in months for *Notropis chrosomus* collected from Moore Creek, Cherokee County, GA from January 2006 to December 2006.

up 14.39%, 9.15%, and 6.1% of all food items, respectively (Table 1). Of all specimens examined, 54.76% of GI tracks were empty. Feeding was not uniform across all months (F= 4.77, df = 11, P < 0.0001) and appeared to be greatest in taxa richness of food items in February and March (n = 5) and peak weight of gut contents (0.031g, SD = 0.014), occurred in March. Feeding appeared to decrease during August with a low mean weight of gut contents (0.006 g, SD = 0.004), taxa richness of food items (n = 2), and 68.75% of GI tracks were empty. In January, 76.5% of all guts were empty with 4 specimens (23.5%) containing detritus, unidentified insect parts, and a single Chironomidae larva. Eviscerated weight explained a low proportion of the variation in the weight of gut contents (r^2 = 9.3% for females and 2.9% for males), but the relationship was significant (P < 0.001 for females, P = 0.029 for males). Eviscerated weight explained an even lower proportion of the variation in taxa richness of food items as regressions were not significant (P = 0.196 for females, P = 0.052 for males).

On 16 May 2007, behaviors associated with spawning in other species (Johnston 1991) were observed for an aggregation of 7 individuals with 3 males in nuptial condition engaging in circle swims and leading the 4 females to a nest of a *Semotilus atromaculatus* (Mitchill) (Creek Chub) at the downstream end of a pool. This behavior was observed for approximately 1 hour in the afternoon. No behaviors directly associated with the expelling of gametes were observed. Mean and individual female GSI peaked in spring, with values greater than 0.15 in specimens from April and May (Fig. 5). Males showed a similar pattern, with GSI values greater than 0.03

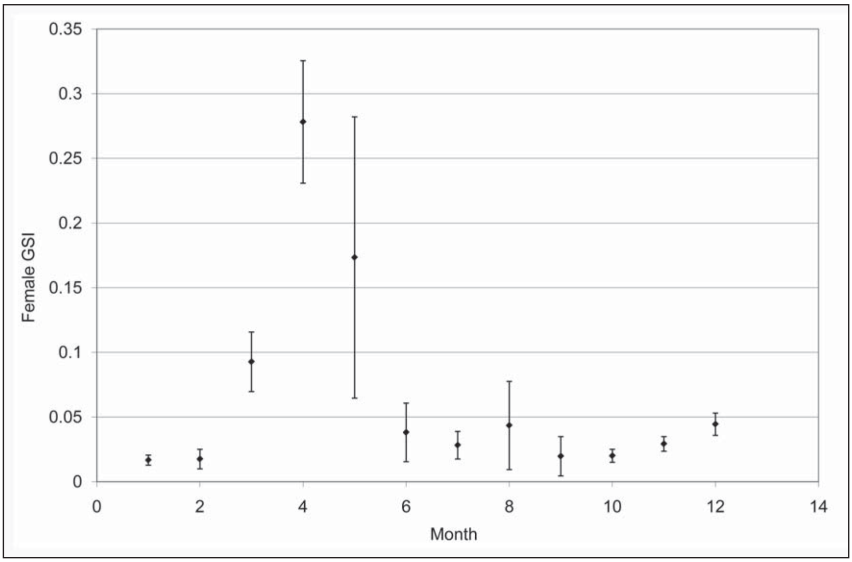

Figure 5. Gonadosomatic index (GSI) by month of the year (1 = January, 2 = February, etc.) ± one standard deviation by months for *Notropis chrosomus* females collected from Moore Creek, Cherokee County, GA between January 2006 and December 2006.

Table 1. Gut contents of *Notropis chrosomus* from Moore Creek, Cherokee County, GA by month. Numbers for each food item indicate the total number of individual items of that food type in all guts examined; detritus and unidentified insect parts are exceptions due to the difficulty quantifying them and are noted by occurrence within a single specimen (e.g., the occurrence of detritus in two specimens from a month is denoted as "2").

	Month													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% of total
# of specimens	16	13	15	13	15	17	22	16	15	24	14	20	200	
Detritus	3	9	7	5	3	3	2	2	3	5		6	49	10.68
Sand			2	1				3					6	1.31
Ova/eggs			22										22	4.79
Nematoda		2											2	0.44
Mollusca														
Physa sp.					2								3	0.65
Insecta														
Unidentified parts	3	6	7	3	7	8	10	4	4	8	2	2	66	14.38
Ephemeroptera						5	13				1	1	20	4.36
Collembola		28											28	6.10
Coleoptera				1						1		1	3	0.65
Lepidoptera										1			1	0.22
Hymenoptera						1	1		1	1			4	0.87
Hemiptera						3							3	0.65
Trichoptera			3		1	1							5	1.09
Diptera														
Chironomidae larvae	1	6	27	91	21	47	1				1	2	205	44.66
Unidentified adults			14		15	2				10			42	9.15
Number empty	13	5	6	6	8	7	11	11	10	13	8	11	115	
% empty	81.25	38.46	40.00	46.15	53.33	41.18	50.00	68.75	66.67	41.76	57.14	55.00		
Total number of items	7	51	82	101	49	70	27	9	8	26	4	12	459	
Mean items/gut	0.41	3.92	5.47	14.43	6.13	4.12	1.23	1.80	0.53	1.08	0.29	0.60		

in specimens from March to June (Fig. 6). The water temperatures of the April, May, and June collections for this study were 20 ºC, 16 ºC, and 25 ºC, respectively. The highest GSI for a single specimen was 0.349 in a female of 53.03 mm SL collected in May. For females, GSI was not uniform among months ($F = 10.48$, df = 11, $P < 0.0001$), but male GSI was not significantly different among months ($F = 1.48$, df = 11 $P = 0.155$). April had the highest mean GSI for females (0.278, SD = 0.047), and March had the highest mean GSI for males (0.048, SD = 0.023). Male GSI in April was also high, with a mean of 0.039 (SD = 0.01). The lowest mean GSI were in January (0.0166, SD = 0.003) for females and October for males (0.009, SD = 0.004). Gravid females were collected from April to June and contained between 400 and 896 (mean 708.92, SD = 162.90) mature oocytes ranging from 0.7 mm to 1.22 mm in diameter (mean = 0.90 mm, SD = 0.167 mm). Ovaries of mature females appeared to contain one class of mature oocytes, and SL was a significant predictor of the number of oocytes ($r^2 = 26.4\%$, $P < 0.0001$).

Discussion

Maximum age appears to be approximately 2 years and is similar for both sexes. The female-to-male ratio (0.96:1) combined with a similar maximum age suggests a similar life span for both sexes. This sex ratio by age class suggests that both males and females have very similar patterns of survival. Very few specimens of either sex appear to reach maximum age, with only 1.5% of all sexed specimens reaching age class 2+. The relatively low number of 0+ specimens collected is likely due to the ease with which specimens

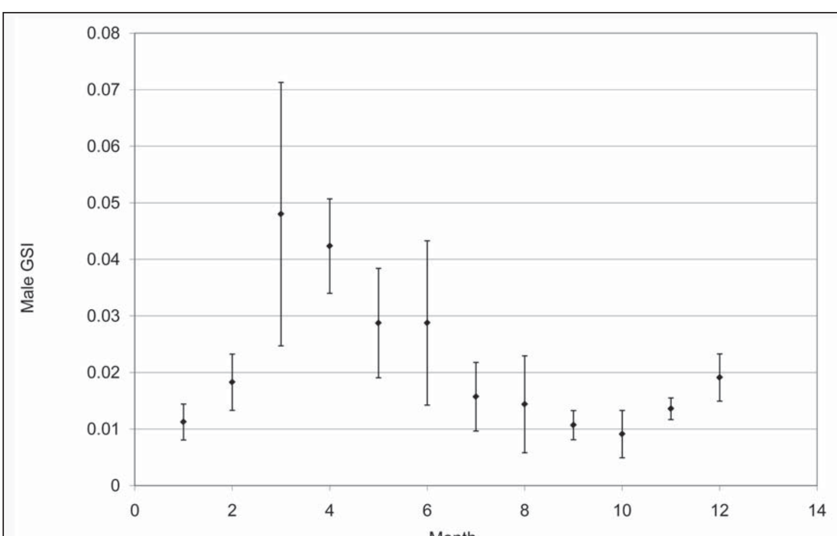

Figure 6. Gonadosomatic index (GSI) by month of the year (1 = January, 2 = February, etc.) ± one standard deviation by months for *Notropis chrosomus* males collected from Moore Creek, Cherokee County, GA between January 2006 and December 2006.

less than 35 mm in SL pass through the 9.5-mm mesh of the 3.3-m x 1.3-m seine. Increases in size as specimens approach 1 and 2 years of age (Figs. 3–4) coincide with increases in feeding and indicates an increased growth rate in the spring.

While the relationship between EW and weight of gut contents was significant, the low r^2 values for these relationships, and the lack of significant relationship between EW and taxa richness of food items suggests size has little impact on diet in *N. chrosomus*. The increase in feeding during late winter and spring months coincides not only with increases in growth, but also slightly precedes the increased energy requirements of gamete production and courtship behaviors. Feeding continues at an increased level through spawning season, declines sharply in late summer, and appears to be nearly absent in January, with 81% of guts empty (Table 1). Not only did mass of gut contents increase as spawning approached, but taxa richness of food items also increased during these months. This pattern may suggest that *N. chrosomus* become less selective in their food items during periods of high caloric demands. Alternatively, as the diet of the syntopic *Notropis xaenocephalus* (Jordan) (Coosa Shiner) also increases in variety during spring (Jolly and Powers 2008), seasonal changes may be due to food availability rather than selectivity of specific food items by *N. chrosomus.* The variety of food items available likely increases during spring due to increased reproductive activity by aquatic invertebrates making them more susceptible to predation (see Thorp and Covich 1991). Increased energetic input by terrestrial insects during summer (and to a lesser extent spring) has been documented in other streams in the Southeast (Cloe and Garman 1996). The increased abundance of terrestrial insects during a period of increased energetic demands provides a relatively simple explanation for these data. Occurrence of ova in the gut of two specimens collected in March is consistent with the observation of *N. chrosomus* eating "loose" eggs by Johnston and Kleiner (1994), and also suggests that *N. chrosomus* are opportunistic feeders during these periods of increased energetic demands.

While Chironomidae (44.6%) are the predominate food item of the gut of *N. chrosomus*, this value is intermediate between the 88.8% of gut contents as Chironomidae in *Hypentelium etowanum* Jordan (Alabama Hog Sucker), a hypothesized bottom feeder (O'Kelley and Powers 2007), and 19.5% as Chironomidae in *N. xenocephalus*, a hypothesized drift feeder (Jolly and Powers 2008), within the same study stretch. This intermediate value also suggests *N. chrosomus* are not particularly selective in their feeding compared to other syntopic species, but rather are opportunistic feeders.

High GSI values in female specimens collected in April and May and low values from July (Figs. 5–6) indicate spawning most likely occurs between late April and early June. All specimens from fall and winter months were latent or maturing (see Heins and Machado 1993), indicating a single spawning season. The water temperatures of the spring collections for this study suggest spawning occurs in 16–25 ºC water. Our observations of spawning behavior were consistent with the findings of Johnston and Kleiner (1994) and indicate that spawning occurs in habitat similar to that used throughout the year, but within this population, egg deposition likely occurs in *Semotilus* sp. nests, as *Nocomis* sp. are absent from Moore Creek and large *Campostoma* sp. are not common.

Examination of gonads and length-frequency distributions (Fig. 2) indicated that sexual maturity occurs by 12 months of age for most individuals, and the maximum age of a little over 24 months suggests no more than 2 spawning seasons for any individual. The occurrence of two specimens over the age of 12 months that did not possess mature gonads suggests that some individuals do not reach sexual maturity until their second spawning season. It is unknown whether this variation in maturation is linked to lifespan. The positive relationship between SL and number of mature oocytes suggests that larger specimens produce more eggs. The positive relationship between age and SL then suggests that older specimens have greater reproductive potential than younger specimens.

Comparison to hypothesized close relatives

Breeding of *N. chrosomus* is comparable to other hypothesized closely related species, *N. leuciodus, N. lutipinnis, N. nubilus,* and *N. rubricroceus* in each having a single breeding season peaking in spring to early summer in water temperatures up to 25 ºC (Boschung and Mayden 2004, Clayton 2000, Etnier and Starnes 1993, Fowler et al. 1984, Outten 1958). Little is known of the biology of *N. leuciodus,* but both *N. chrosomus* and *N. nubilus* appear to reach sexual maturity mostly at 12 months of age (with a few individuals not reaching maturity until 24 months) and have a maximum lifespan of less than 3 years. *Notropis lutipinnis* and *N. rubricroceus* differ in having maximum life spans of 5 years and sexual maturity occurring at two years of age (Clayton 2000, Outten 1958). All hypothesized close relatives spawn over nests of *Nocomis* sp., *Campostoma* sp., or *Semotilus* sp. These associations are hypothesized to be mutualistic relationships (Johnston 1994a, b), with host species benefiting from predator dilution and associative species benefiting from the parental care of the host. The observed range of mature oocytes size (0.97–1.22 mm) in *Notropis. chrosomus* appears to be smaller than that of *N. lutipinnis, N. rubricroceus* and *N. nubilus* at 1.4–1.7, 1.6, and 2.1 mm, respectively (Clayton 2000, Fowler et al. 1984, Outten 1958). While methods of quantifying fecundity are variable across studies, *N. lutipinnis* examined by McAulliffe and Bennett (1981) had up to 286 eggs, Clayton (2000) estimated up to 786 eggs per female, and Outten (1958) reported up to 1174 eggs per female.

The diet of *N. chrosomus* appears to be similar to that of hypothesized close relatives in feeding habits as 83% of food items were invertebrates with ova, detritus, and inorganic materials consisting of the rest of the gut contents. As with *N. lutipinnis* and *N. rubricroceus*, the bulk of the invertebrates were aquatic and terrestrial insects. However, as insects represent the bulk of available food items, all species are hypothesized to be largely opportunistic feeders. (Clayton 2000, Outten 1958)

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